# Cretaceous sedimentary units of Mangyshlak Peninsula (western Kazakhstan)

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**ABSTRACT**
The Cretaceous succession of the Mangyshlak Region is reviewed. Two periods in the geological history of this region are recognised. Sedimentary units are determined for period on the base of detailed stratigraphy. Usually the units are separated by unconformities, differing in range and significance. The time of terrigenous sedimentation extends from the earliest Cretaceous to the early Turonian. The Neocomian succession was formed under changing Tethyan/Boreal influence. The main interruption in marine sedimentation took place in the early Hauterivian (which is probably missing in the region)-Barremian interval, during which continental sediments were deposited. Aptian to early Turonian deposits were formed within the European Palaeobiogeographical Region with a few Boreal invasions. The time of carbonate sedimentation in the "Chalk sea" Basin of the European Palaeobiogeographic Region began in the late Turonian and continued through the Maastrichtian.

**KEY WORDS**
Mangyshlak,
Kazakhstan,
Cretaceous,
stratigraphy,
unconformity,
palaeobiogeography.

**RÉSUMÉ**

*Les unités sédimentaires crétacées de la péninsule du Mangyshlak (Kazakhstan occidental).*

La série crétacée de la région du Mangyshlak est revue. Deux périodes dans l'histoire géologique de cette région sont reconnues. Les unités sédimentaires sont déterminées sur la base d'une stratigraphie détaillée. Habituellement, les unités sont séparées par des discordances, d'âge et de signification différents. La sédimentation terrigène s'étend du Crétacé basal au Turonien inférieur. La succession du Néocomien s'est formée sous le changement d'influence boréale-téthysienne. La principale interruption dans la sédimentation marine a lieu dans l'intervalle de l'Hauterivien inférieur (qui manque probablement dans la région)-Barrémien, durant lequel se déposent des sédiments continentaux. Les dépôts de l'Albien-Turonien inférieur se sont formés dans la province paléobiogéographique européenne avec quelques invasions boréales. La sédimentation carbonatée du bassin de la « Mer de la craie » du bassin paléobiogéographique européen débute au Turonien supérieur et se poursuit pendant le Maastrichtien.

**MOTS CLÉS**
Mangyshlak, Kazakhstan, Crétacé, stratigraphie, discordance, paléobiogéographie.

## INTRODUCTION

This report includes biostratigraphic data concerning Cretaceous high resolution stratigraphy of the Mangyshlak Mountains (Fig. 1). The data were collected during their field trips by Naidin, Beniamovskii and Kopaevich (1980-1986), and by Baraboshkin (1989-1995). They were implemented by data from the geological literature.

The stratigraphic data are based or correlated with the standard biostratigraphical scheme for western "Boreal" Europe, taken from recent publications (Carter & Hart 1977; Robaszynski *et al.* 1982; Birkelund *et al.* 1984; Wood *et al.* 1984; Robaszynski 1987; Schoenfeld 1990; Rawson *et al.* 1996). We are not discussing details and problems of these stratigraphic correlations, which fall outside the scope of the present report.

## STAGE BOUNDARIES

Investigation of palaeogeography and sequence/event stratigraphy must be based on a precise and reliable zonal stratigraphical scheme with preferably a wide correlation potential. For their investigations, the previous Russian authors have used the standard zonal scale for the Lower Cretaceous (Luppov *et al.* 1976, 1983, 1988; Saveliev 1992; Baraboshkin 1992, 1996, 1997) and for the Upper Cretaceous the stratigraphical scheme of the Mangyshlak, where the foraminifera zonal scheme is closely correlated with zonal schemes based on macrofauna (Naidin *et al.* 1984a, b, 1995).

### LOWER CRETACEOUS

The Lower Cretaceous of Mangyshlak is characterised by a terrigenous deposition in shallow water to near-shore and continental environments. The stratigraphy of the Lower Cretaceous of Mangyshlak is based mainly on ammonite distribution (Fig. 2). It was mainly developed by Semenov, Luppov, Sokolov, Saveliev, Bogdanova. The biostratigraphic scale based on bivalves is particularly useful and was developed by Mordvilko, Nikitina, Saveliev, Bogdanova. The foraminifera scale results from research by Myatlyuk and Vasilenko. Application of a foraminifera scale is limited for the Neocomian because of strong facies control, but is very useful for the Aptian-Albian interval.

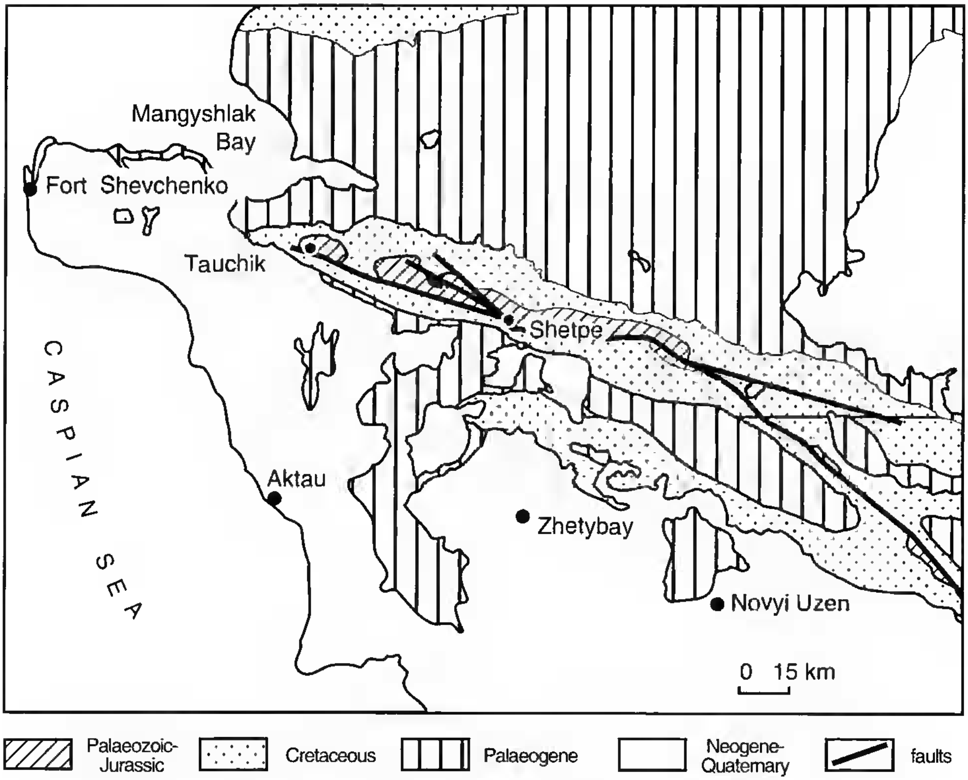


FIG. 1. — Geological map of Mangyshlak.

The Jurassic/Cretaceous boundary coincides with a major unconformity. Berriasian sediments are represented by a shallow water sandy-silty succession, with marl and limestone intercalations, and oyster banks. The sediments are irregularly distributed because of later erosion. The Jurassic/Cretaceous boundary in Mangyshlak is determined by the appearance of ammonites of the Tethyan family Berriasellidae: *Riasanites* Spath, *Neocosmoceras* Blanchet, *Subalpinites* Mazenot, etc. and of some representatives of the Boreal family Craspeditidae: *Surites* Sasonov (Luppov *et al.* 1988). The benthic assemblage also contains a mixture of Boreal and Tethyan bivalves, gastropods, brachiopods and other fauna: *Buchia volgensis* (Lahusen), *B. okensis* (Pavlow), *B. uncitoides* (Pavlow) (Boreal); *Myophorella loewinson-lessingi* (Renngarten), *Rutitrigonia laeviscula* (Lycett) (Tethyan) and others. It is interesting, that foraminifera data demonstrate the absence of Boreal elements (Luppov *et al.* 1988). The fauna indicates the presence of the upper Berriasian only and the absence of the Volgian to middle Berriasian interval. The faunal assemblage suggests that marine conditions disappeared near the Jurassic/Cretaceous boundary and after a short Tethyan transgression, Boreal water penetrated in the area.

The base of the Valanginian is marked by an erosional unconformity and by the presence of phosphoritic conglomerates. It was recognised by the appearance of Boreal Valanginian ammonites and buchiids. Valanginian sediments were formed in shallow water environments. They are represented by various terrigenous facies with intercalations of carbonates. The Valanginian is characterised by the development of a Boreal ammonite fauna: *Nikitinoceras* Sokolov, *Polyptychites* Pavlow, *Dichotomites* v. Koenen (Luppov *et al.* 1983). There is the only evidence for the presence of Tethyan fauna is the upper Valanginian ammonite *Neohoploceras* sp., figured

| STAGE | SUBSTAGE | MEDITERRANEAN SCALE (Hoedemaeker et al. 1995, simplified) ZONE | SUBZONE | MANGYSHLAK (Saveliev et al. 1963; Saveliev 1992; Luppov et al. 1983, 1988; with changes by Baraboshkin, this paper) ZONE, SUBZONE |
|---|---|---|---|---|
| ALBIAN | UPPER | *Stoliczkaia dispar* | *Stoliczkaia (S.) dispar* | *Pleurohoplites studeri* |
| | | | *S. (F.) blancheti* | *Callihoplites vraconensis* |
| | | *Mortoniceras inflatum* | | *Mortoniceras (Mortoniceras) inflatum* |
| | | | | *Semenovites (Semenovites) michalskii* |
| | | | | *Semenovites (Planihoplites) pseudocoelonodus* |
| | | | | *Semenovites (Semenovites) tamalakensis* |
| | MIDDLE | *Euhoplites lautus* | | *Anahoplites rossicus* |
| | | | | *Hoplites (H.) perarmatus* |
| | | *Euhoplites loricatus* | | *Daghestanites daghestanensis** |
| | | | | *Anahoplites intermedius* |
| | | *Hoplites dentatus* | *Hoplites spathi* | *Hoplites (H.) spathi* |
| | | | *Lyelliceras lyelli* | *Lyelliceras (L.) lyelli* |
| | LOWER | *Douvilleiceras mammillatum* | | *Pseudosonneratia (Isohoplites) eodentata** |
| | | | | *Otohoplites crassus* |
| | | | | *Protohoplites (H.) puzosianus* |
| | | | | *Sonneratia (Eosonneratia) caperata* |
| | | | | *Sonneratia (Eosonneratia) rotula* |
| | | | | *Sokolovites subdragunovi** |
| | | | | *Sonneratia (Eosonneratia) solida* |
| | | | | *Sonneratia (Globosonneratia) perinflata* |
| | | *Leymeriella tardefurcata* | | Beds with *Leymeriella (Neoleymeriella)** |
| | | | | *Anadesmoceras strangulatum* |
| | | | | *Leymeriella (Leymeriella) acuticostata** |
| | | | | *Arcthoplites (Subarcthoplites) probus** |
| | | | | *Arcthoplites (Arcthoplites) jachromensis* |
| | | | | *Leymeriella (Leymeriella) recticostata** |
| APTIAN | UPP. | *Hypacanthoplites jacobi* | | MISSING |
| | | *Acanthohoplites nolani* | | *Nolaniceras nolani* |
| | | | | *Acanthohoplites aschiltaensis* |
| | MID. | *Parahoplites melchioris* | | *Parahoplites melchioris* |
| | | *Epicheloniceras subnodosocostatum* | | *Epicheloniceras subnodosocostatum* |
| | LOWER | *Dufrenoya furcata* | | *Dufrenoya furcata* |
| | | *Deshayesites deshayesi* | | *Deshayesites deshayesi* |
| | | *Deshayesites weissi* | | *Deshayesites weissi* |
| | | *Deshayesites tuarkyricus* | | |
| BARREMIAN | | | | CONTINENTAL FACIES |
| HAUTERIV. | UPP. | | | ? |
| | LOW. | | | MISSING |
| VALNGINIAN | UPPER | *Neocomites (Teschenites) pachydicranus* | | *Dichotomites bidichotomus* |
| | | *Saynoceras verrucosum* | | |
| | LOWER | *Busnardoites campylotoxus* | | *Polyptychites polyptychus* |
| | | *Thurmanniceras pertransiens* | | *Nikitinoceras hoplitoides** |
| | | *Thurmanniceras otopeta* | | |
| BERRIASIAN | UPPER | *Fauriella boissieri* | | *Riasanites rjasanensis** |
| | | | | *"Euthymiceras sp."** |
| | | | | *Transcaspiites transfigurabilis** |
| | MIDD. | *Tirnovella occitanica* | | MISSING |
| | LOW. | *Berriasella jacobi* | | |

FIG. 2. — Ammonite zonation of Lower Cretaceous of Mangyshlak. Stars mark ammonite zones, revised or proposed for the first time in this paper.

from Mangyshlak by Gordeev (1971). The benthic assemblage is mixed and contains both Boreal and Tethyan elements, bivalves: *Buchia keyserlingi* (Lahusen), *B. sibirica* (D. N. Sokolov) (Boreal), *Iotrigonia scapha* (Agassiz), *Litschkovitrigonia tenuituberculata* Saveliev; corals: *Thamnasteria digitata* Fromentel, *Stereocoenia collinaria* (Fromentel) (Tethyan).

The Valanginian/Hauterivian boundary is very difficult to recognise in Mangyshlak, and in the whole Peri-Caspian Region. The lower Hauterivian was traditionally described from Mangyshlak according to Saveliev. He cited records of *Dichotomites bidichotomus* (Leymerie) (Saveliev 1958; Saveliev & Vasilenko 1963). According to up-to-date interpretation, this ammonite should be referred to the upper Valanginian of mainly Boreal Province. Luppov *et al.* (1983) referred shell-rich beds and sandstones to the Hauterivian on the base of the presents of the brachiopods *Cyclothyris irregularis* (Pictet), *C. gillieroni* (Pictet) and of the corals *Actinostrea colliculosa* Trautschold (in East Karatau). The only record of the lower Hauterivian *Lyticoceras* sp. is from the Peri-Caspian Region (Koltypin 1970). We assume that this identification was a erroneous, because the inadequate understanding of *Lyticoceras* Hyatt, 1900 in the stratigraphic literature of that time. If this were the case then there is no real evidence for the existence of lower Hauterivian sediments in that area. The other reason for the absence of lower Hauterivian in Mangyshlak is the general palaeogeography. Sediments of that age are missing over most of the Russian Platform (in the north), in the northern part of the Scythian Platform (to the west); in Kazakhstan and Turkmenia (to the south-east) they are present mainly in continental facies. In the Tuarkyr area (situated between the Great Balkhan and Mangyshlak) the lower Hauterivian is also missing. This is supported mainly by ostracod data (Alekseeva *et al.* 1972).

The presence of upper Hauterivian in Mangyshlak is can be discussed, but is more plausible, because sediments of that age cover the eastern part of the Russian Platform (including the Peri-Caspian) and the Scythian Platform. It is possible that part of the continental red-coloured unit (Barremian, according to traditional stratigraphy) belongs to the upper Hauterivian as was supposed by Saveliev & Vasilenko (1963).

The Hauterivian/Barremian boundary is not characterised by ammonites in Mangyshlak. Usually in the Peri-Caspian area the boundary is placed at the disappearance of the upper Hauterivian Boreal ammonites *Simbirskites* Pavlow and *Craspedodiscus* Spath and the appearance of the belemnite *Oxyteuthis* Stolley. The Barremian age of red- and rainbow-coloured sands, silts and clays (Kugusem Formation) is supported by a specific foraminiferal assemblage; *Gyroidinoides sokolovae* Mjatliuk and *Conorbinopsis barremicus* (Mjatliuk) by comparison with Peri-Caspian sections (Myatlyuk 1980) and by ostracod data (Korotkov & Shilova 1982). Sediments of that type are widely distributed in the Turanian Platform area. It was the time of separation from the Russian Platform Basin caused by sea-level fall and followed by the freshening of the water.

The Barremian/Aptian boundary is recognised more easily in the region by the appearance of the lower Aptian ammonite *Deshayesites* Kasansky. The base of the Aptian coincides with a regional transgressive surface and condensed beds with *Deshayesites deshayesi* (Leymerie *in* d'Orbigny), *D. dechyi* (Papp), *Tropaeum* sp. and other northern Tethyan faunal elements (Saveliev & Vasilenko 1963). The Aptian succession is represented by a sandstone-siltstone shallow marine unit with clays at the base, containing numerous small unconformities. The three Aptian substages are presented in this area, but the upper Aptian succession is condensed in the basal phosphoric horizon of the lower Albian. The ammonite assemblage known from Mangyshlak (*Deshayesites* Kasansky, *Parahoplites* Anthula, *Epicheloniceras* Casey, *Acanthohoplites* Sinzow) demonstrates the influence of northern Tethyan water.

The Aptian/Albian boundary is defined at the base of *Leymeriella tardefurcata* zone, which is widely distributed in the region. The Albian succession is formed by shallow-marine and near-shore terrigenous deposits. It was investigated in detail (Saveliev 1973, 1992). Records of *Arcthoplites jachromensis* (Nikitin) together with leymeriellids (Saveliev 1973) are very important for characterising the short-term influence of Boreal seas and this taxon is a good for correlating Arctic and Tethyan scales (Baraboshkin 1992, 1996). The faunal assemblage is very rich in ammonites and contains mainly European forms (*Leymeriella* Spath, *Sonneratia* Bayle, *Otohoplites* Steinmann, *Hoplites* Neumayr, *Callihoplites* Spath, etc.). The Tethyan influence is clearly visible in the lower Albian (*Douvilleiceras* Grossouvre abundance), lower middle Albian (appearance of rare *Lyelliceras*) and from the middle upper Albian onwards (where *Mortoniceras* Meek, *Stoliczkaia* Neumayr and heteromorphs occur frequently). At the same time, an endemic evolution took place (the lower upper Albian, when *Semenovites* Glasunova was widely distributed). The faunal distribution indicates a relative sea separation. The Albian succession is very complete in terms of ammonite stratigraphy (Saveliev 1992), but contains numerous small stratigraphical gaps, marked usually by phosphorites. The style of deposition during the Albian changed from shallow open marine in the beginning to near-shore in the end typical for Peri-Caspian (Baraboshkin 1996, 1997). The top of the Albian is regionally eroded and some of the Albian ammonites are found reworked, in condensed basal phosphoritic horizon of lower Cenomanian.

### Upper Cretaceous

The Cenomanian/Turonian boundary is at the top of the *Sciponoceras gracile* zone. The belemnite *Praeactinocamax plenus* (Blainville) is also characteristic for the terminal part of the Cenomanian. The lower Turonian boundary position practically corresponds to appearance of the *Mytiloides* inoceramid lineage and this level is an event which can be traced throughout the Tethyan and Boreal realms.

The Turonian/Coniacian boundary coincides with the first appearance of *Cremnoceramus rotundatus* (*sensu* Tröger *non* Fiege: Kauffman *et al.* 1996). This level is lower than the firsr *Cremnoceramus deformis* (Meek), which was mentioned in previous Russian schemes.

The Coniacian/Santonian boundary coincides with the base of the *Cladoceramus undulatoplicatus* zone. It is a very good level, because the remains of this taxon is very easily identified.

The Santonian/Campanian boundary is at the base of the *Gonioteuthis granulata quadrata* zone in western "Boreal" Europe. This level coincides almost exactly with the disappearance of *Marsupites testudinarius* (Schlotheim) in Mangyshlak as elsewhere. Zonal species of belemnites not been found here. *Gonioteuthis* Bayle species do not extent to the east beyond the Donets Basin. Assemblages of other belemnites, *Actinocamax laevigatus* Arkhangelsky, determine the age of this interval as early Campanian (Naidin *et al.* 1984b).

The Campanian/Maastrichtian boundary is very sharp: mass findings of *Belemnitella langei* Jeletzky group are suddenly replaced by mass findings of *Belemnella*.

The Maastrichtian/Danian boundary is very sharp also, because a stratigraphical gap is present and shown by the disappearance of many macrofaunal groups: ammonites, belemnites, inoceramids.

The micropalaeontological scheme for the Upper Cretaceous of Mangyshlak is very detailed and contains 26 foraminiferal subdivisions (Fig. 3). The identification of zones is based on tracing species assemblages. At different time intervals the representatives of different genera took a leading stratigraphic significance: *Gavelinella* Brotzen for the Cenomanian/Turonian, *Stensioeina* Brotzen for the Coniacian-Santonian, *Bolivinoides* Cushman for the Campanian/Maastrichtian.

The common occurrences of *Gavelinella cenomanica* (Brotzen) and *Rotalipora appeninnica* (Renz) are referred to the lower Cenomanian, and appearance of *Lingulogavelinella globosa* (Brotzen) is related to the middle-upper Cenomanian.

The lower Turonian interval of foraminifera evolution is marked by the presence of large *Hedbergella* Broennimann & Brown and *Whiteinella* Pessagno (zone à « Grandes Globigerines »), while the middle-upper Turonian interval is determined by appearance and evolution of *Marginotruncana* sp. and *Gavelinella moniliformis* (Reuss).

The abundance of *Marginotruncana* Hofker or "Grandes Rosalines" increases near the Turonian-

Coniacian boundary deposits. This boundary is determined by the mass appearance of *Gavelinella praeinfrasantonica* (Mjatliuk) (= *G.* aff. *vombensis*), *Reussella kelleri* Vassilenko and also by small *Stensioeina*. Mass occurrence of typical *Stensioeina granulata granulata* (Olbertz), *Gavelinella thalmanni* (Brotzen), *G. vombensis* (Brotzen) (= *G. infrasantonica*), *Osangularia whitei whitei* (Brotzen) are a typical for the upper Coniacian. *Stensioeina exculpta exculpta* (Reuss) appears in the terminal part of the Coniacian and is especially numerous in the lower Santonian.

The Santonian/Campanian boundary is considered to be within the *Bolivinoides strigillatus* zone. The appearance and mass occurrence of *Stensioeina pommerana* Brotzen, *Gavelinella clementiana clementiana* (d'Orbigny), *Bolivinoides decoratus* (Jones) are typical for the lower Campanian, those of *Brotzenella monterelensis* (Marie) for the middle Campanian. The upper Campanian is determined by the appearance of *Cibicidoides voltzianus* (d'Orbigny) followed by *Bolivinoides draco miliaris* Hiltermann & Koch, *Bolivina kalinini* (Vassilenko) (= *B. incrassata* (Reuss), narrow specimens), upwards by *Brotzenella taylorensis* (Carsey) and in the most terminal part by *Angulogavelinella gracilis* (Marsson).

The Campanian/Maastrichtian boundary is determined on the basis of the appearance of *Neoflabellina reticulata* (Reuss) and *Bolivina decurrens* (Ehrenberg), but also on the presence of abundant *Angulogavelinella gracilis* (Marsson). The middle part of the lower Maastrichtian is differentiated by *Brotzenella complanata* (Reuss) and the upper part by *Bolivinoides draco draco* (Marsson) and *Anomalinoides subcarinatus* (Cushman & Deaderick). The upper Maastrichtian is characterised by the appearance of *Brotzenella praeacuta* (Vassilenko) and of *Anomalinoides pinguis* (Jennigs) and in its terminal part by the of occurrence of *Hanzawia ekblomi* (Brotzen) and of *Pseudotextularia elegans* (Rzehak).

This stratigraphical scheme allows correlation of all Upper Cretaceous sections in Mangyshlak with those of many areas of western part of "Boreal" Europe: Anglo-Paris Basin, western Germany and lowland part of Poland.

## THE SUCCESSION OF SEDIMENTARY UNITS

"Sedimentary units" stand for relatively conformable succession of genetically related strata bounded at the top and base by unconformities or by correlative conformities. This is a modification of an earlier usage by Sloss (1976). There are many different visible and invisible gaps and unconformities in the investigated area (Saveliev 1971; Naidin 1987; Naidin & Kopaevich 1988).

### Lower Cretaceous sedimentary units

The Lower Cretaceous succession contains many different stratigraphical gaps and several large unconformities. Mostly they are erosional in origin because of shallow conditions of the whole succession. The main gaps and flooding surfaces, which separate different sedimentary units, could be determined in the following levels (Fig. 3).

The lower Berriasian: a gap appeared during significant palaeogeographical rebuilding and interrupting of sedimentation. Hence, an unconformity is visible at the base of the upper Berriasian (it overlies different parts of the Mesozoic or Palaeozoic sequence). There are many small gaps inside the Berriasian interval which are only of local significance.

The gap and unconformity between the upper Berriasian and lower Valanginian extend over 1-2 ammonite zones. Usually, this level is marked by erosional surface with phosphorites. Also typical for Mangyshlak is that the lower Valanginian overlays the Middle Jurassic, and highly condensed phosphoric horizons were deposited. The highest condensation is seen in the *Nikitinoceras hoplitoides* zone, but the base of the Valanginian (an analogue of the *Neotollia klimovskiensis* zone of Siberia) is missing.

In the Valanginian-Barremian interval a hiatus includes the complete lower Hauterivian. The gap is usually indicated by a thin basal level with phosphorites, softground and an erosional surface development. The existence and completeness of other parts of the Hauterivian/Barremian succession is under discussion and needs additional palaeontological evidence.

The Barremian/Aptian boundary hiatus extends over 1-3 ammonite zones. It is teptesented by a

| Symbol | Zone | |
|---|---|---|
| $m_2$ | ***Hanzawaia ekblomi***, *Anomalinoides pinguis*, *Gavelinella* ex gr. *danica*, *Pseudotextularia varians*, *P. elegans* | XXVI |
| $m_1^3$-$m_2$ | ***Brotzenella praeacuta***, *Cibicides kurganicus*, *Gavelinella pertusa*, *Tappanina selmensis* | XXV |
| $m_1^3$ | ***Bolivinoides draco draco***, *Coleites crispus*, *Gavelinella midwayensis*, *Stensioeina caucasica* | XXIV |
| $m_1^2$ | ***Brotzenella complanata***, *Spiroplectammina suturalis*, *Gavelinella welleri*, *Anomalinoides subcarinatus*, *Bolivina incrassata incrassata*, *B. incrassata crassa* | XXIII |
| $cp_3^3$-$m_1^1$ | ***Angulogavelinella gracilis stellaria***, *Neoflabellina reticulata*, *Osangularia navarroana*, *Gyroidina globosa*, *Cibicidoides bembix*, *Bolivina decurens*, *Bolivinoides delicatulus*, *B. peterssoni*, *Reussella minuta* | XXII |
| $cp_3^3$ | ***Brotzenella taylorensis***, *Neoflabellina praereticulata*, *Bolivina incrassata incrassata*, *Pseudouvigerina cristata*, *Bolivinoides giganteus* | XXI |
| $cp_3^2$ | ***Bolivinoides draco miliaris***, *Eponides frankei*, *E. conspectus*, *Gavelinella cayexi mangyshlakensis*, *Bolivina kalinini*, *Gemellides orcinus*, *Rugoglobigerina rugosa* | XX |
| $cp_3^1$ | ***Cibicidoides voltzianus***, *Heterostomella foveolata*, *Plectina ruthenica*, *Globoratalites emdyensis*, *Gavelinella clementiana laevigata*, *Globotruncana morozovae* | XIX |
| $cp_2$ | ***Brotzenella monterelensis***, *B. menneri*, *Gavelinella clementiana usakensis*, *Arenobulimina convexocamerata*, *Heterostomella praefoveolata*, *Orbignyna sacheri*, *O. ovata*, *Voloshinovella tertia*, *V. laffitei* | XVIII |
| $cp_1^3$(up) | ***Cibicidoides aktulagayensis***, *Plectina convergens* | XVII |
| $cp_1^3$(low) | ***Cibicidoides temirensis***, *C. montanus*, *Eponides biconvexus*, *Bolivinoides laevigatus laevigatus*, *Bolivinitella galeata* | XVI |
| $cp_1^2$ | ***Bolivinoides decoratus decoratus***, *B. granulatus*, *Osangularia cordieriana*, *Globigerinelloides volutus* | XV |
| $cp_1^1$ | ***Gavelinella clementiana clementiana***, *G. dainae*, *Neoflabellina rugosa*, *Stensioeina pommerana*, *Reussella pseudospinulosa*, *Bolivinoides laevigatus finitima*, *Globotruncana arca* | XIV |
| $st_2$-$cp_1^1$ | ***Bolivinoides strigillatus***, *Ataxophragmium orbignynaeformis*, *Gavelinella stelligera*, *Globotruncana arcaformis* | XIII |
| $st_2$ | ***Osangularia whitei polycamerata***, *O. whitei crassa*, *O. whitei whitei*, *Gavelinella* ex gr. *stelligera*, *Cibicides excavatus* | XII |
| $st_1$ | ***Stensioeina granulata perfecta***, *S. granulata incondita*, *S. exsculpta gracilis* | XI |
| $cn_2$-$st_1$ | ***Stensioeina exsculpta exsculpta***, *Gavelinella vombensis*, *G. umbilicatula*, *Cibicidoides eriksdalensis* | X |
| $cn_2$ | ***Stensioeina granulata granulata***, *Spiroplectammina embaensis*, *Valvulineria laevis*, *Gyroidina turgida*, *Globorotalites michelinianus*, *Osangularia whitei whitei*, *Gavelinella vombensis* (= *G. infrasantonica*), *G. thalmanni*, *G. costulata*, *Bolivinita eleyi* | IX |
| $cn_1$ | ***Reussella kelleri***, *Gavelinella praeinfrasantonica*, *Gavelinella kelleri*, *G. costulata*, *Stensioeina granulata kelleri*, *Marginotruncana coronata* | VIII |
| $t_3$ | ***Ataxophragmium nautiloides***, *Gavelinella* ex gr. *costulata*, *Cibicidoides praeeriksdalensis*, *Marginotruncana renzi* | VII |
| $t_2$ | ***Gavelinella moniliformis***, *G. ammonoides*, *Spiroplectammina praelonga*, *Gaudryina variabilis*, *Globorotalites multiseptus*, *Reussella carinata*, *Marginotruncana lapparenti*, *M. marginata*, *Hedbergella agalarovae* | VI |
| $t_1$(up) | ***Globorotalites hangensis***, *Spiroplectammina cuneata*, *Gaudryina subserrata*, *Gyroidina nitida*, *Valvulineria lenticula*, *Gavelinella vesca*, *Cibicidoides apprima* | V |
| $t_1$(low) | ***Hedbergella holzli***, *H. portsdownensis*, *Whiteinella brittonensis*, *W. archeocretacea*, *W. baltica*, *Globigerinelloides bentonensis* | IV |
| $cm_{2\text{-}3}$ | ***Lingulogavelinella globosa***, *Brotzenella berthelini*, *Gavelinella vesca* | III |
| $cm_1$ | ***Gavelinalla cenomanica***, *G. baltica*, *Lingulogavelinella orbiculata*, *Cibicides polyrraphes polyrraphes*, *Neobulimina numerosa*, *Hedbergella caspia*, *Thalmanninella appenninica* | I- II |

FIG. 3. — Foraminifera zonation of Upper Cretaceous of Mangyshlak.

condensed horizon containing small phosphatic pebbles with reworked lower Aptian fauna.

The Aptian/Albian boundary gap including the upper Aptian-basal lower Albian (2-3 ammonite zones to the whole middle-upper Aptian and basal Albian). It is an important unconformity marked by a strong erosional and environmental break. Traces of upper Aptian are recognisable in rewashed phosphatic pebbles in Mangyshlak sections.

There is an unconformity in the topmost Albian (usually less than one ammonite zone, but in some Mangyshlak sections – half of the stage is missing). A gap separates Lower and Upper Cretaceous sequences. It is easily recognisable by a thick phosphoritic horizon and by an unconformity at the base. All hiatuses are more extensive in easterly direction in the marginal parts of the basin. Because of the gaps mentioned above, the following sequences were recognised in the Lower Cretaceous of Mangyshlak.

Upper Berriasian-Valanginian unit (I): the unit is separated by a very strong unconformity at the base of the upper Berriasian and by an erosional surface at the top of the Valanginian. It is a very complex member with many small gaps, especially in the lower Valanginian part. This unit begins with coarse-grained near-shore sediments and finishes with relatively deep-water clayey sediments for the latest stage of sequence development. It is important that the unit was formed mainly under Boreal water influence with short-term penetration of Tethyan water at its beginning.

Upper Hauterivian (?)-Barremian unit (II): the unit includes mainly subaeral sediments. There is an erosional surface at the base of the sequence and another erosional surface at its top.

Aptian unit (III): the unit starts at the transgressive part of the lower Aptian with an erosional surface and an unconformity at its base. The upper limit of unit III is an erosional surface with the condensed upper part of the Aptian stage. This unit was formed during a transgressive-regressive cycle, finished during the late Aptian in near-shore to subaeral (partially) environments. The deepest conditions followed by an anoxic event existed during the latest early-middle Aptian. The deposition took place under Tethyan water influence.

Albian unit (IV) is characterised by a rapid transgression and a slow late early to latest Albian shallowing. It is separated by an erosional surface from the Aptian. At the top, there is a strong unconformity with erosional surface and phosphoric condensation overlain by the Cenomanian. Unit IV is represented by a transgressive-regressive cycle with a change of conditions at the end of the early Albian-beginning of the middle Albian. During this time, the sandy to silty-clayey shallow marine sedimentation changed into a near-shore environment. The Albian development of Mangyshlak Basin was affected by Boreal influence at the beginning, by separation from other basins in the early late Albian and by an increased influence of Tethyan waters in the latest Albian.

### Upper Cretaceous sedimentary units

Six sedimentary units compose the succession of the Upper Cretaceous in Mangyshlak (Fig. 4). Units I-II are differentiated from those with terrigenous composition: sands, sandstones and clays. Units III-VI contain carbonate clays, marls and chalk. There are "black beds" on the Cenomanian/Turonian boundary in the stratigraphically complete sections.

There is only one regional unconformity in the Upper Cretaceous succession of Mangyshlak area: at the Cenomanian/Turonian boundary, but relatively complete sections also exist. Many small hiatuses similar to hard grounds are visible in the carbonate part of all sections of Mangyshlak (Naidin & Kopaevich 1988). The genesis of these hardgrounds is explained by a combined effect of climatic and eustatic agents. It is suggested that carbonate rocks containing hardgrounds are a modification of rhythmically bedded strata.

The clay intercalations or "clays" differ from the carbonate sediments above and below in the abrupt decrease in the $CaCO_3$ amount. It is assumed that the "clays" result from submarine early carbonate biogeochemical dissolution at the sea floor caused by an abrupt increase in biological productivity of the pelagic zone (Naidin & Kopaevich 1988).

The Upper Cretaceous interval in Mangyshlak can be divided in six units. These units and their

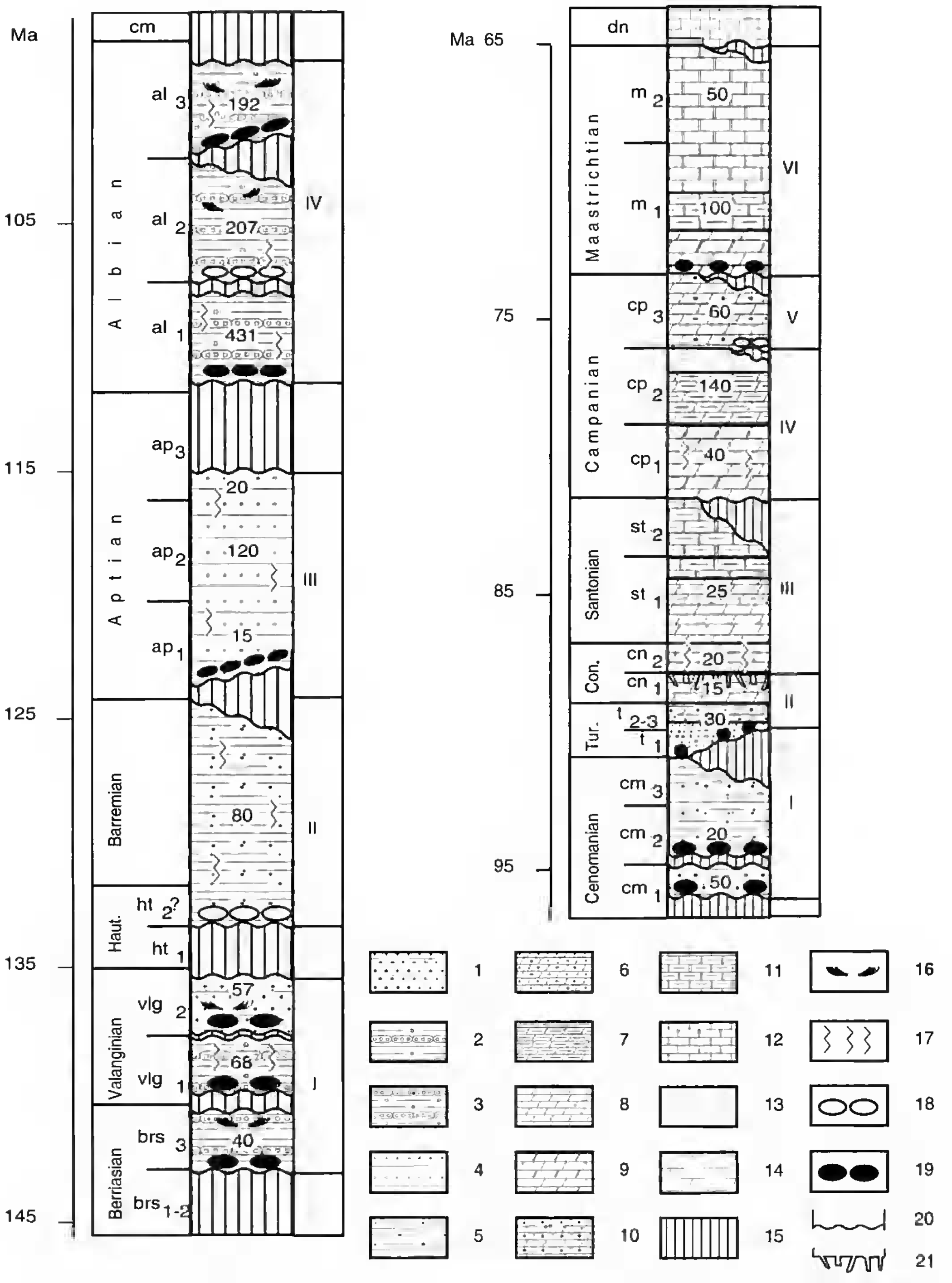


FIG. 4. — Sedimentary units of the Cretaceous of Mangyshlak. **1**, clayey sands; **2**, clays, siltstone and sandstone alternations; **3**, sands, siltstone and sandstone alternations; **4**, soft sandstones; **5**, clayey siltstones; **6**, sandy marls; **7**, clayey marls; **8**, marls; **9**, dolomitised marls; **10**, marls-sandy marl alternations; **11**, clayey dolomites; **12**, dolomites; **13**, limestones; **14**, carbonated clays; **15**, main stratigraphical unconformities; **16**, cross-bedding; **17**, bioturbation; **18**, conglomerates; **19**, phosphoric nodules and pebbles (phosphorite horizon); **20**, erosional surface; **21**, hardground. Roman numerals agree with sedimentary units.

boundaries were formed under the influence of sea-level changes, but some of them have a tectonic origin.

Unit I (Cenomanian-lower Turonian): the remains of oysters, other bivalves and phosphatic nuclei of ammonites are usually present. The foraminifera zones I-III characterise this sequence. This unit contains a very poor assemblage of benthic foraminifera, but the Cenomanian/Turonian boundary interval is characterised by large *Hedbergella-Whiteinella* planktonic foraminifera association.

Unit II (middle-upper Turonian-lower Coniacian) has a hiatus in its base. Its size is different in different parts of the area – sometimes a part of the Cenomanian or all of the middle-upper Cenomanian and the lower part of the lower Turonian are missing. There is a phosphatic horizon at the base of unit II. This is a condensed section, which was formed partly under the influence of sea-level changes (Hancock 1992). The beginning of this unit may coincide with mark 89.8 Ma in the curve of shore onlap of Haq *et al.* (1987) (Naidin 1995). Inoceramids, brachiopods, rare ammonites and echinids are present. The foraminifera zones IV-VIII characterise this succession. Benthic/planktonic foraminifera ratio is always high, but decreases near Turonian/Coniacian boundary ("Grandes Rosalines" interval).

Unit III (upper Coniacian-Santonian) was formed during an unstable eustatic situation. There is a sharp hardground surface at the base of this unit. Traces of eustatic transgression are visible towards the end of this unit, its beginning may coincide with mark 85 Ma of the main curve of Haq *et al.* (1987). This is the "Marsupites transgression" in Western Europe and in Mangyshlak. Remains of inoceramids and crinoids are usually present here. The foraminifera zones IX-XIII characterise these units. Benthic/planktonic foraminifera ratio is also high.

The boundary of units III and IV (or Santonian-Campanian boundary) shows a small condensation at this level. Belemnite rostra are abundant and remains of inoceramids are rare inside this unit (Lower Campanian). Many small echinids (*Offaster* Desor, *Galeola* Klein) are found in the lower part of this unit. The upper part is characterised by belemnites, rare ammonites and abundant small and large echinids also. Very rich assemblage of foraminifera is present, benthic foraminifera prevail. The beginning of Unit V (middle Campanian) coincides with mark 77.5 Ma. The eustatic rise of sea-level took place at this time and the transgression peak probably coincide with mark 73.5 Ma of Hancock (1992) (Naidin 1995).

Unit VI consists of chalk of Maastrichtian age in Mangyshlak. The lower boundary of this unit is different in different places: a continuous transition or a small or big hiatus in the southern Aktau Mountains. The upper Maastrichtian part of the unit has a regressive character with short transgressive impulse towards the end, so called "*elegans* transgression" (mark 67.5 or 68.5 Ma: Wicher 1953). The benthic/planktonic foraminifera ratio decreases sharply at this level. This Late Maastrichtian short but intensive transgression is clearly revealed by sedimentological and structural properties and was also shown by the last outburst in the appearance of new globotruncanid taxa (Maslakova 1978). Many different fossil remains exist in this unit: belemnites, ammonites, oysters, brachiopods, echinids. The top of unit VI coincides with the eustatic fall of the sea-level at the Maastrichtian/Danian boundary. The biological crisis is fixed at this boundary, all remains of ammonites, belemnites, inoceramids and practically all planktonic foraminifera disappeared. All the sections show a hiatus in the base of the Danian, only two Mangyshlak sections (Koshak and Kyzylsai) are marked by "boundary clay" with iridium in this interval.

## CONCLUSION

From the data presented, the following stages in the development of Mangyshlak during the Cretaceous can be recognised.

1. A time of terrigenous sedimentation:

– sedimentation in a basin with longitudinal connections with strong boreal influence and smaller Tethyan invasions: upper Berriasian-Valanginian;

– sedimentation in continental conditions: upper (?) Hauterivian-Barremian;

– sedimentation in a basin with longitudinal to latitudinal connections, with Tethyan influence: Aptian;
– sedimentation in a basin longitudinal to latitudinal, but predominantly latitudinal connections with short Boreal and Tethyan incursions and with partial basin isolation: Albian;
– sedimentation in a latitudinal-oriented basin of European Palaeobiogeographic Region: Cenomanian-early Turonian.
**2.** A period of carbonate sedimentation in the "Chalk sea" Basin of European Palaeobiogeographic Region: middle Turonian-Maastrichtian.

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